

SPIRE CORPORATION

A Feedback-Controlled, Metallo-Organic Chemical Vapor Deposition Reactor

Laser diodes are the tiny workhorses in many industrial and consumer products. Every CD-ROM player has at least one, and many printers and photocopiers have a large array of them. More than 20 million laser diodes are needed each year for this market alone, and the number is growing.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

One Star

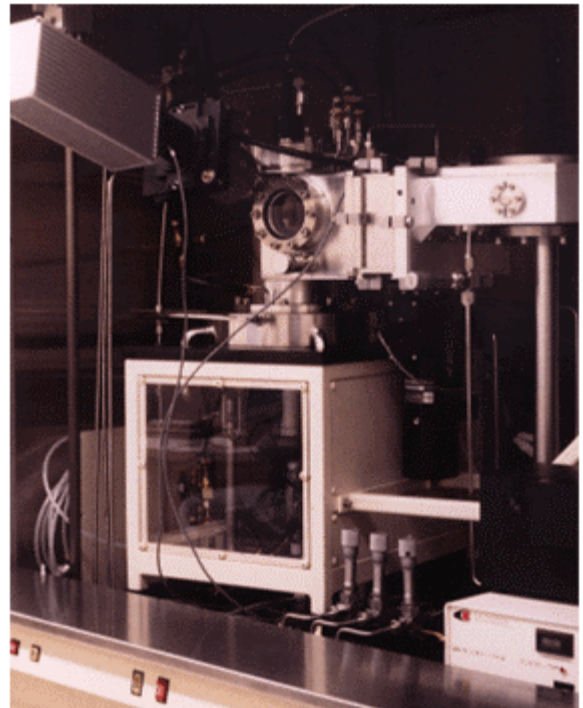
Advanced Fabrication Control for Improved Electronic Devices

This ATP project with Spire Corporation developed a new way to make laser diodes and other optoelectronic devices. Founded in 1969, Spire is a specialty manufacturer of semiconductor wafers and metallo-organic chemical vapor deposition (MOCVD) equipment. The company's new method makes possible the manufacture of individual lasers and laser arrays at lower cost and with higher performance characteristics.

Spire built and demonstrated an advanced MOCVD reactor designed for the fabrication of laser diodes. Laser diodes are intricate multilayer structures generally grown by MOCVD on compound semiconductor wafers. Researchers developed in-process sensors to monitor the development of layers on the substrate, as well as control systems to automatically adjust the many process parameters. They demonstrated that the new technology can control the growth rate of the layers. They also showed that the new reactor performed better than conventional reactors in terms of epitaxial layer uniformity over the entire wafer, as well as run-to-run consistency. These two factors can contribute significantly to reducing the cost of making laser diodes.

Potential for Commercial Products

The project did well technically, and limited commercialization is under way. Spire is pursuing its original plan to produce and sell reactors and license the technology to other manufacturers, and it is in discussions with several potential customers. The



The advanced metallo-organic chemical vapor deposition reactor constructed with funding from ATP.

company also planned to produce low-cost laser diode arrays in competition with foreign producers, but that market did not develop.

Spire has successfully used the prototype reactor to perform customer-specific research and development

PROJECT HIGHLIGHTS

Project:

To develop an advanced feedback-controlled, high-throughput, metallo-organic chemical vapor deposition (MOCVD) reactor for fabricating low-cost, high-quality laser diode arrays.

Duration: 6/15/1992 — 3/31/1995

ATP Number: 91-01-0263

Funding (in thousands):

ATP	\$1,223	56%
Company	973	44%
Total	\$2,196	

Accomplishments:

Spire achieved the project's research goal and afterward conducted additional, company-funded development to commercialize the technology. A prototype reactor is being used for commercial wafer production and customer-specific development work. Signs of the project's success include the fact that the company:

- published four papers and presented several others at professional conferences during the award period;
- demonstrated the ability to grow epitaxial wafers with high-quality uniformity of composition and thickness over an entire wafer 2.25 inches in diameter;
- demonstrated the ability to fabricate vertical cavity surface emitting lasers (VCSELs) with state-of-the-art performance characteristics;
- published a 1997 update on use of the ATP-funded reactor, "In Situ Monitoring and Control for MOCVD Growth of AlGaAs and InGaAs," in the Journal of Electronic Materials;
- received \$356,000 from two large manufacturers for development of advanced VCSEL epitaxial wafers

and wafer production processes, with an additional \$450,000 to \$750,000 expected in the near future; and

- expanded sales of commercial epitaxial wafers (mostly for lasers and light-emitting diodes), with sales revenue of about \$200,000 in 1998.

Commercialization Status:

Limited commercialization has been under way since 1996. The ATP-funded technology has been incorporated into an MOCVD reactor being used for commercial production of optoelectronic epitaxial wafers. These include VCSEL epitaxial wafers that are being developed for high-speed laser printing. Spire is also using the reactor for two development projects funded by other companies.

Outlook:

Spire expects to produce substantial numbers of VCSEL devices in the future. Because the market is growing rapidly, the company is positioned to exploit its superior in-house epitaxial wafer growth capability, based on the ATP-funded technology, to produce large quantities of whole epitaxial wafers, as well as wafers processed into optoelectronic devices ready for packaging.

Composite Performance Score: * *

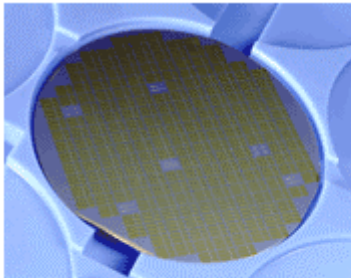
Company:

Spire Corporation
1 Patriots Park
Bedford, MA 01730-2396

Number of Employees: 180 at project start,
150 at the end of 1997

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A wafer populated with arrays of vertical cavity surface emitting lasers.

and to produce epitaxial laser wafers of a demanding structure. One customer has invested more than \$250,000 with Spire to develop vertical cavity surface emitting laser (VCSEL) wafers and plans to invest another \$450,000 in the effort in the near future. A VCSEL emits light in a cylindrical beam vertically from its surface and may offer significant advantages over edge-emitting lasers in some applications. This customer may also buy an MOCVD reactor from Spire in the next two years, following completion of the initial

development project.

Spire is focusing on use of the new feedback-controlled reactor for growing laser wafers for VCSELs and edge-emitting lasers. VCSELs would be used in high-speed laser printers and in optical interconnects for computer links, and edge-emitting lasers would be used in solid-state laser pumps and in measurement and material

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processing applications. The company contracted with another large manufacturer in late 1997 to develop VCSEL arrays for advanced optical computer interconnects. Spire has already been paid \$106,000 for the project and could potentially receive another

\$300,000. If the development work succeeds, Spire believes it will enable the company to enter the huge market for optical interconnect components.

ATP Project Opens Doors

If the ATP funds had not been available, Spire would not have done the project, company officials say. The ATP award enabled Spire to overcome technical barriers to volume production of VCSEL wafers, some of which contain more than 650 epitaxial layers. These complex structures had been previously grown only in a few laboratories and in small lots and sometimes virtually by hand. Spire's new capability, in turn, has attracted an entire new line of customers.

The company's new method makes possible the manufacture of individual lasers and laser arrays at lower cost and with higher performance characteristics.

The potential for alliances with research and development partners is now high, and Spire is already working on advanced device development projects with several companies. The benefits to users of new devices made from these complex wafers can be significant. The ATP-funded reactor enables production of many kinds of wafers at lower costs. It also enables the production of some devices, made from VCSEL wafers, that could not be fabricated any other way. The benefits, however, can occur only if the company's limited commercialization expands into full-scale success, and it is still too early to tell whether that will happen.